SEMI-ANNUAL STATUS REPORT

NASA Grant NsG 426

(California Institute of Technology)

1 Oct. 64 - 31 March 65

The present report covers the second half of the second year of operation under NASA Grant NsG 426. As in previous status reports, this report is divided into a number of sections which describe the activities of the more-or-less separate groups sponsored by this Grant, followed by an over-all summary of staff, expenditures, and bibliography.

For the benefit of the reader who may not be interested in technical detail, the following brief summary will provide a general picture of the activities of the various groups.

SUMMARY

I. Cosmic Rays (Neher)

Dr. Neher's activity under this Grant is principally directed towards the manufacture, and field operation of a number of his very accurate absolute ionization chambers. Some of these have been completed and flown to balloon altitudes from Thule, Greenland. Several flights were made at the time of the launching of Mariners 3 and 4, to obtain a comparison of polar low-energy cosmic ray intensities near the earth, with readings from a similar chamber aboard the Mariner spacecraft. The flights at Thule, and the chamber aboard Mariner 4, both showed a 6% increase in the intensity of low-energy cosmic rays between 3 December 1964 and 16 February 1965. A very recent flight at Thule showed that the low energy cosmic rays are now within 4% of reaching the maximum intensity they attained in the previous maximum period in 1954.

II. Cosmic Rays (Vogt and Stone)

Drs. Vogt and Stone are engaged in a research program directed towards the investigation of the astrophysical aspects of cosmic radiation and the radiation environment of the earth. This investigation is carried on by means of particle detector systems flown on spacecraft and from balloons. At the present time three experiments are underway or in preparation, and in the laboratory, a program of detector system development is also being carried on.

The three experiments underway are:

1. A satellite experiment is to be flown on the OGO-C and -D spacecraft, the first of which is scheduled to be launched during summer 1965. This experiment, which is being carried out jointly by Dr. Stone at Caltech, and Drs. J.A. Simpson and C.Y. Fan at the University of Chicago, will measure the time-dependent energy spectrum of protons between 0.7 MeV and 40 MeV, and of alpha particles between 2 MeV and 160 MeV. This experiment should provide valuable information on the mechanism of acceleration of high-energy particles in solar flares and the propagation of those particles to the earth. In addition, study of the cut-off momenta as functions of spacecraft location and time should add to the understanding of the earth's magnetosphere.

2. A detector system designed to measure the energy spectra of protons and alpha particles between 400 keV and 1 GeV per nucleon, and of electrons between about 100 MeV and 1 GeV, is being prepared for balloon flight during summer 1965 from Ft. Churchill, Canada, and in early 1966 from Page, Arizona. This experiment represents an upwards extension of the energy range of the preceding one, and should provide further information on the solar acceleration and interplanetary propagation of cosmic ray particles. In addition, it should also be possible to measure the solar modulation effects upon galactic cosmic rays arriving from outside the solar system.

3. A high-energy electron spectrometer involving an airborne, digitized spark chamber is under construction which will measure the energy spectrum of electrons between about 100 MeV and several GeV with great sensitivity. This detector system is planned for balloon flight during early 1966 from Page, Arizona, and is expected to provide information on the electron content of galactic and solar cosmic rays, and possibly indirectly on galactic magnetic fields.

III. Theoretical Astrophysics (Christy)

For the past several years Dr. Christy has pursued a fundamental investigation of the machanisms of instability of pulsating variable stars such as the cepheids and the RR Lyrae variables. With the help of an IBM 7094 computer he has succeeded in working out the systematics of the instabilities of the RR Lyrae stars, and has extrapolated these results to the cepheid variables.

IV. Interplanetary Magnetic Fields and Plasmas (Davis, Haerendel, and Siscoe)

The main efforts of this group are directed towards the theoretical interpretation of magnetometer data from spacecraft, particularly that of Mariners 3 and 4, and the theoretical investigation of the structure and dynamics of the magnetosphere of the earth and other planets. Some characteristic patterns in the Mariner 4 magnetometer data have been identified, and their physical basis is being sought. Other investigations underway are:

a) a theoretical study of the rate of diffusion of heavy-ion gas clouds in the earth's upper atmosphere, to obtain information in the density, temperature, and molecular weight of the environmental gas from certain rocket data; and

b) a theoretical study of the effect of electric currents in the magnetospheric "tail" of the earth upon geomagnetic disturbances and storms.

V. Infrared Astronomy (Neugebauer, Leighton and Ulrich)

This group is engaged in astrophysical observational studies in the infrared spectral range. Up until the present time the investigations have been ground-based, utilizing the several available atmospheric "windows". The principal objective at present is the completion of a survey of the sky in two infrared spectral wavelength ranges, 0.7 - 1.0 microns, and 2.0 - 2.5 microns. The survey instrument consists of a 62 inch, f/1 plastic paraboloidal mirror capable of 2' arc resolution, with a liquid nitrogen cooled detector array at its principal focus. This infrared telescope is situated on Mount Wilson and is operated almost every clear night.

Other activities of the group include:

1. Multi-band photometric measurements of the infrared intensities of unusual infrared sources found in the sky survey.

2. Preparation of a liquid hydrogen cooled, mercury-doped germanium detector array for survey use at 8-13 micron wavelength.

3. Construction of a special lead sulfide detector system (utilizing infrared polaroid) to test sources for linear polarization in the 2.0 - 2.5 micron range, and

4. Adaptation of an existing infrared spectrimeter (on loan from JPL) to permit spectral distribution measurements at the Mount Wilson 60 inch or 100 inch telescopes.

VI. Planetary Spectroscopy (Münch, Neugebauer and Ridgeway)

For several years Dr. Münch of the Mount Wilson and Palomar Observatories has been engaged in a study of the high-dispersion spectra of the planets, particularly Mars, Jupiter and Saturn. It was principally from measurements obtained by him and his colleagues that the presently indicated low value of 15 millibars for the surface atmospheric pressure of Mars was first derived. Because of the difficulty of this measurement and its importance in the study of Mars by space probes, especially Martian landers,

many people are attempting to improve upon the existing measurements. Recently, Drs. Münch and Neugebauer have endeavored to measure the Martian atmospheric parameters using certain carbon dioxide bands in the 2-micron wavelength range. These measurements are still underway.

A further activity of this group is the construction of an atomic vapor resonance detector of the Blamont type for the study of certain solar spectrum lines. Hopefully, this technique will also be applicable to the study of stellar or even interstellar spectral lines.

VII Instrumental Development (Dennison, Rule and Oke)

An activity of a somewhat different nature from the others is that of the instrumental development group, whose operations are partially supported under the NASA Grant. What this group does is not, in itself, pure astrophysical research, but its activities are among the most important being carried on at the Mount Wilson and Palomar Observatories in terms of the eventual yield of new astrophysical results.

Its major concern is to assure that the major telescopes are adequately coupled with the proper up-to-date accessory instruments such as spectographs, photometers, spectrum scanners, data handling systems, etc., so as to assure their utmost utility and efficiency for the widest variety of observations.

A major task of this group during recent months was the development, construction, installation and successful testing of a pulse-counting spectrum-scanning photometer system for the coudé spectograph of the 100 inch telescope. This system is to be used by Münch in his observations of Mars. A preliminary version of a similar pulse-counting automated data recording system has been successfully tested at the 200 inch telescope, and a more complete, comprehensive system is under construction. Actual results obtained to date show that the over-all efficiency of the major telescopes, in terms of information recorded per night of operation may be increased by a factor of at least two, and perhaps as much as four, by using such data-handling techniques.

FURTHER DESCRIPTION OF ACTIVITIES

I. Cosmic Rays (H.V. Neher)

In the last report, the problem of the temperature coefficient of the ionization chambers was described. The inherent sensitivity and reproducibility of this type of ion chamber is so great that even a temperature coefficient of a small fraction of a percent per degree centigrade would seriously limit its precision because of the unknown fluctuations in temperature to which the instrument might be subjected during flight. This problem has been attacked and a batch of 50 instruments has been assembled and temperature tested with encouraging results. The temperature coefficients of these instruments range from less than 0.003% per degree centigrade, up to 0.025%, all but one being less than .015%/^{o}C. Since the temperature change of the instrument during a balloon flight is usually less than 10^{o}C, the neglect of temperature changes will now introduce a negligible error in all cases, whereas errors of up to a percent were previously occasionally present.

In connection with the program with Mariner 4, balloon flights have been made at Thule just after Mariner 4 was launched and also during February of 1965. These flights allow one to compare the cosmic radiation in space with that near the geomagnetic pole and close to the top of the atmosphere. During each of these periods, one balloon reached a residual air mass of less than 2 g/cm^{-2}. Useful comparative data were obtained and the results are being reduced. Unfortunately, the ion chamber - Geiger counter combination on Mariner 4 has ceased to function due to power supply failure. However, it is still planned to return to Thule in April to finish the series of flights that was scheduled last year.

II. Cosmic Rays (R. Vogt and E.C. Stone)

The three experiments mentioned in the summary are here described in more detail:

OGO-C and -D

Experiment 5008 (POGO) is a joint experiment with J.A. Simpson and C.Y. Fan of the University of Chicago. Experiment packages are fabricated at Chicago, while the tests and calibrations listed below have been Caltech responsibilities. Those marked X have been carried out, and the tests are all proceeding on schedule. One flight unit is on the spacecraft at the present time.

Activity	Proto-type	FU-1	FU-2
Pulser calibration Pulse height analyser Discriminators Ratemeter	X	X	X
Cyclotron calibration		X	X
Tandem Van de Graaff calibration			X
Bench testing at STL	X	X	X
Integration of OGO-C spacecraft	X	X	X
Integrated systems tests at STL	X	X	X

The p, α, e balloon-borne experiment

This instrument consists of two counter telescopes. The 0.4 to 300 MeV/nucleon spectra are measured by a dE/dx-range system composed of one surface-barrier solid state detector (100μ thick, 2.5 cm^2 sensitive area with guard ring) and six lithium-drift detectors (1000μ depletion depths, 4.5 cm^2 with guard ring) separated by tungsten absorbers. The spectra above 350 MeV/nucleon are measured be a dE/dx - Čerenkov system composed of a lithium-drift detector and a lucite Č-radiator.

The status of this experiment can be broken down into the following major categories:

a) Counters and detectors

1. A sample lithium-drift detector gave 31% resolution for 1 BeV electrons during synchrotron tests last December. A full complement of detectors, tested with Bi^{207}, $Sn^{113-119}$ and Hg^{203} sources in the lab, are ready for synchrotron tests.

2. Special low-mass holders were designed for the solid state detectors. The result is an integrated unit which can be safely handled and properly tested.

3. Plastic scintillators for the anti-coincidence counters are being supplied by the Nuclear Enterprises Company. A system of coating the scintillators directly with a high-reflectance paint has been developed. No change in the characteristics of this coating has been found over a 9-month interval.

4. All anti-coincidence counters are mounted in milled aluminum and magnesium cases in a manner suitable for satellite application. Also, all photomultipliers are potted in a standard housing with a special low-density, white silastic compound.

5. Synchrotron tests of the ruggedized RCA 4439 photomultiplier provided information on optimum dynode voltage distribution and gain.

6. Lucite Č-radiators were tested with $\beta = 1$ particles from the Caltech synchrotron. Various tubes were tested, resulting in the choice of the EMI 6097. Resolution was 26% full width at half maximum. A 2 cm lucite Č-radiator will yield a usable threshold of $\sim$ 360 MeV for protons.

b) Electronics

1. A quality control system has been instituted for the testing of

all resistors, capacitors, diodes, and transistors. All gondola components have been subjected to the same severe tests required for spacecraft applications.

2. Low-power, temperature-stable circuitry designed for satellite application has been built on modular plug-in cards. The 17 different cards, each $2\frac{1}{2}$ x 4" with 35-pin ELCO connectors, are combined into two sub-assemblies totalling 80 cards for each gondola.

c) Recording and playback hardware

1. A laboratory playback system, utilizing a computer tape deck, is operational, allowing conversion of the 16-channel flight tapes to perforated paper tape.

d) Other support items

1. A 14-station battery charger has been designed for field and lab use in recharging the flight battery (AgZn) packs.

2. A quick readout instrument using type 6977 triodes has been designed for visual display.

High-energy electron spectrometer (involving developments of an airborne digitized spark chamber system):

Instrument development based on "wire" spark chambers using ferrite core readout and on other planned detector systems has continued. Fifteen new single-gap chambers of various types were constructed and tested with various gases and operating voltages. Two types of chambers are used, with ground-electrodes consisting of:

a) lines of various width etched on copper-clad epoxy boards;
b) stainless steel wires (0.003" diameter) stretched on phenolic frames. High voltage electrodes were either of the "wire" type, solid metal plates, or solid metal plates covered with dielectric on the gap side. A typical gap had an area of 4" x 4" (24 wires/inch) with spacings of the order of $\frac{1}{4}$" .

With each type of chamber, gas mixtures and operating voltages have been found for which the chambers typically show the following properties:

1. Efficiency for detecting a charged particle: > 98%.
2. Probability that a spark caused by a charged particle be accompanied by a "spurious" spark anywhere else in the chamber: ∽ 3%.
3. Probability that chamber will spark under high voltage pulsing in the absence of a clear particle track: < 0.2%.
4. Spark spreading (mean number of adjacent wires where cores are set by a spark): ∽ 2.5.

Typical gas mixtures used in the chambers were: 90% Ne + 10% He and He + A mixtures. The Ne mixture allows typically lower operating voltages (∽ 4 - 5 kv compared to 6 - 7 kv for He + A) but give greater spark spreading (∽ 3 instead of 2.5 wires avg.). The addition of ethanol vapor (by bubbling 30 - 50% of the gas through ethanol) decreased spurious sparking and spreading.

The dielectric covering of the high voltage plate leads to less spark spreading (∽ 2 wires instead of 2.5 - 3) than in exposed plates, but to no other noticeable changes.

No significant difference between the properties of "true wire" chambers and "etched strip" chambers could be discovered so far.

Tests made at the Caltech synchrotron show that a simple track count in 6 chambers, mutually separated by 1 to 2 radiation lengths of lead, presently allows a full width at half maximum energy resolution of ∽ 50% at 1 BeV. Further chamber development is in progress.

For support electronics, a fast, nanosecond coincidence circuit operable in a balloon gondola has been designed. This circuit will trigger the high voltage pulser from a fast counter telescope.

A gas Čerenkov counter (2 atmospheres of SF_6) with a threshold of 16 BeV for protons and 8 MeV for electrons is presently being tested. Its dimensions are 4" diameter by 11" long, with a quartz window photomultiplier tube viewing a parabolic reflector from outside the particle beam.

III. Theoretical Astrophysics (R.F. Christy)

The systematics of the computed instabilities of RR Lyrae stars have now been worked out. It is also possible to extrapolate these results to provide approximate results for the instability region of Cepheids. The high temperature boundary of the instability strip for giants in the HR diagram is approximately given by

$$\frac{(M/M_\odot)^{1/2}}{(L/L_\odot)^{1/2} \times (T_e/10^4)^5} = K ,$$

where M is the stellar mass, L the luminosity, and T_e the effective temperature. The constant K depends slightly on the hydrogen-helium ratio and on the metal content. For Population II stars and 30% He by mass, $K \approx 2/3$. The existance of the instability also requires that

$$\frac{L/L_\odot}{M/M_\odot} > 30 .$$

It has also been found that the shortest period of the fundamental period instability is approximately dependent only on the luminosity and is given by $P_{min}^{(days)} \approx 0.057 \ (L/L_\odot)^{0.6}$. This permits a determination of the luminosities of cluster type RR Lyrae variables as $L/L_\odot \approx 38$ or $M_b \approx +0.75$ from the observational knowledge that the periods of the shortest period type a variables are about 0.5 days.

If this law is extrapolated to the Cepheid region, it suggests that the shorter period Cepheids (less than about 9 days) are in fact pulsating in the first harmonic. A few calculated models tend to confirm this suggestion.

It also follows from these results that the masses of RR Lyrae variables are in the neighborhood of 0.5 $M_{\odot}$ which indicates that considerable mass loss must have taken place.

IV. Interplanetary Magnetic Fields and Plasmas (L. Davis Jr., G. Haerendel and G.L. Siscoe)

During the past six months a major share of the activity of this group was centered around the Mariner 4 magnetometer experiment. During the launch phases of Mariners 3 and 4, both magnetometer and other data were used to obtain important information on the orientation of the spacecraft. Subsequent to the launch phase, much effort has been devoted to the development of computer programs for the reduction of the final extract data tapes which are beginning to be available. Some characteristic patterns of magnetometer data have been identified, and an attempt to identify their physical basis is in process.

Dr. Haerendel is studying the sedimentation of artificial gas clouds of heavy ions released in the upper atmosphere, as in the experiments of the Max-Planck Institute fur Extraterrestrische Physik in Munich, and is finding how this can be used to give information on the density, temperature, and molecular weight of the upper atmosphere. This work is virtually complete. He is also studying the effect on the protons in the radiation belts with energies below about 10 MeV due to perturbations in the geomagnetic field and finds support for the view that the source of the protons is at or outside the magnetopause.

Dr. Siscoe is studying the effect of the magnetospheric tail current on geomagnetic disturbances and storms. The investigation indicates tentatively that the effect on sudden impulses and sudden commencements is small. The possibility that the main phase of large magnetic storms is

strongly affected by the tail currents is being studied by means of an explicit field-line-cutting model.

The work of a graduate student, Mr. J.R. Jokipii, on the acceleration of electrons by a first order Fermi process near shocks is progressing well and appears to explain some of the observed features of the spectrum. Two other graduate students, who are working on the interaction between the interplanetary magnetic field and the angular momentum of the solar wind and on the interaction of the interplanetary magnetic field with the moon, are still at a rather preliminary phase of their work.

V. Infrared Astronomy (G. Neugebauer, R.B. Leighton and B.T. Ulrich)

The major effort of this group has been directed toward carrying out a survey of objects in the sky that radiate strongly in the 2.0 to 2.5 micron wavelength region. This effort can be divided into two parts: The operation of the 62-inch infrared telescope, and the reduction of the data which is recorded on an eight-channel strip-chart recorder. Other activities include measurements with a multiband infrared photometer at the Mount Wilson 60-inch telescope, and development of an 8-14 micron detector system to be used with the 62-inch infrared telescope.

a) Data Collection

The telescope has been in essentially continuous operation since September 1964 surveying a region of the sky three degrees wide in declination and up to twelve hours long in right ascension, each clear night. No basic changes have been made in the operation of the telescope since the last status report although a new, more efficient dewar has been constructed.

In late January, it was necessary to begin the survey again when the 2.0 to 2.5 micron filter was found to be defective, transmitting all wavelengths longer than 1.6 microns. For relatively hot stars, the failure of the filter is of little consequence, because atmospheric

transmission and the detector sensitivity limits the wavelengths detected mainly to the regions between 2.0 and 2.5 and between 3.5 and 4.0 microns, and the hot stars emit much more strongly in the shorter wavelength band. For the cool stars of primary interest in this survey, however, a large amount of energy might be radiated in the 3.5 to 4.0 micron band and would cause the stars to appear cooler than is actually the case. The data taken between September and January have been useful, however, in locating potentially very cool stars, of which about a dozen with an I - K magnitude difference greater than $\sim$ 7 have been found. A double monochromator which will allow frequent measurement of the wavelength response of the detector-filter combination while at liquid nitrogen temperature without dismantling the dewars is now being set up.

b) Data Reduction

Dr. Ulrich has been designing a computerized data analysis system. The position and amplitude of each signal on the permanent strip chart record is digitized and recorded on punched paper tape by a digital voltmeter attached to a scanning table.

Each object which is of sufficient strength to be observed by the detecting system appears, because of the raster scanning sequence, between two and six times on the strip chart record. The Caltech IBM 7090 computer is utilized to identify signals which come from the same source and to make refined estimates of the right ascension and declination for each source. Actually, by using the fact that the detector cell sensitivity varies over its length in a measurable way, it is even possible to measure declinations to a precision of 0.5 arc, which is smaller than the cell size or even of the circle of confusion of the mirror now in use. The program also corrects each peak for the sensitivity of the detector at the declination at which it occurred. Additions to the present program are in progress to more completely automate the data reduction once the strip chart has been scanned, and produce computer-drawn star charts that can be compared directly to the

Schmidt survey plates to identify interesting objects. To find corrections to the coordinates of the telescope a magnetic tape catalog of red stars will be searched to find identifiable objects. The program also will normalize each night's data according to measured values of standard stars to account for fluctuations in measured star intensity due to variations in atmospheric water vapor content and in detector system sensitivity.

c) Infrared Photometry

Over the past six months the program of infrared photometry has been continued by a graduate student, E.E. Becklin. Using the 60-inch telescope at Mount Wilson Observatory, he has obtained absolute measurements of the fluxes in the band from 2.0 to 2.5 microns, and in the band from 3.3 to 4.0 microns, of the two reddest objects so far detected by the survey. Also completed recently was a spatial mapping of the flux from the Orion Nebula in the 2.0 to 2.5 micron region with a resolution of .25 minutes of arc which shows an appreciable amount of continuum radiation from the areas between the stars.

d) 8-14 Micron Photometry Using the 62-inch Telescope

The possibility of using the 62-inch telescope for photometry in the 8-14 micron region has been investigated by a second graduate student, Evan Hughes, using a 2 mm cube of mercury-doped germanium as detector. The main problem in this wavelength region is a large background of chopped radiation from the surroundings reflected in the vibrating mirror. To eliminate this background, a new dewar with a set of four push-pull detectors, similar to the lead sulfide detector arrays used in the survey program, is being constructed. With this array it is planned to search for discrete sources of radiation in the vicinity of the galactic center.

VI. Planetary Spectroscopy (G. Münch, G. Neugebauer and S. Ridgeway)

a) Infrared spectral observations of Mars

Drs. Münch and Neugebauer are attempting to make a more reliable

measurement of the surface pressure of Mars by observing the absorption caused by the large amount of Martian CO_2. A measurement of this absorption in any single band can give at best the product of the amount of CO_2 and the atmospheric pressure; it is therefore necessary to measure the absorption in at least two spectral regions.

As a first attack to this problem, rotational lines of the CO_2 band at 2.05μ have been measured in the spectrum of Mars and the Moon using the coudé spectograph of the 100-inch telescope and a PbS detecting system. The strength of the absorption in the lines J = 12, 14 and 16, of the R-branch in this band, was measured through an exit multislit of three elements, each with a width of 3 Å or half the line separation. This multislit was swept slowly over the absorption line pattern, and the ratio between the signal when the multislits coincided with the peaks between the absorption lines, and when they coincided with the lines, was measured. For an Elasser band model, one can show analytically that this ratio depends almost linearly on the product of the effective pressure and amount of absorber, as this product increases without limit. It is conjectured that the same linear dependence will hold for more realistic models, and the data obtained from spectra of the Moon verify this conjecture, up to air masses around 3.0. The ratio measured in the spectrum of Mars, with a narrow equatorial slit and a terrestrial air mass near unity, on the other hand, has a value corresponding to that of the moon at an air mass of ∽ 3. This index of the strength of the CO_2 absorption is believed to be more accurate than conventional broad-band absorption measures, which always are affected by the uncertainty with which the background "continuum" may be fixed.

The interpretation of the index ratio measured in Mars, in terms of an effective pressure and amount of CO_2 depends, among other factors, on the temperature of the Martian atmosphere. In order to obtain a measure of the temperature, both the Moon and Mars spectrum were measured using a multislit with ten elements matched to cover the lines from J = 6

to J = 26 in the P-branch of the 2.06μ CO_2 band, each slit having a width of 1.25 A. The effective spectral resolving power was thus near 6000. Again, the ratio of the maximum to minimum powers received as the multislit was swept over the line pattern was measured, as a function of air mass, both in the Moon and in Mars. The preliminary analysis of the data suggests that this ratio is a steeper function of terrestrial air mass for Mars than for the Moon, indicating that the high rotational lines in the Mars spectrum are appreciably weaker than in the earth's.

It should be noted that the techniques which have been developed to observe the 2.06μ band can easily be extended to be used in other infrared regions for making stellar observations.

b) Photoelectric spectrum scanner

Tests were made in November - December 1964, with the DC detecting system of the coudé scanner indicated the presence of the (1,2,3) band of CO_2, but also showed that an increase in both resolving power and speed was desirable if precise measures of this kind were to be made. For this reason it was decided that a pressure-scanned Fabry-Perot interferometer with a finesse and free range adjusted in such a manner that the fringes coincide with the lines of the band, should be added behind a single exit slit. The number of lines to be observed is to be varied by closing or opening the exit slit. The multiplexing and wide-slit advantages of the interferometer should provide far better signal-to-noise ratios for the detection of weak bands. In addition, the efficiency of the detection system was enhanced by installing photomultipliers of extremely high quality, and digital pulse couting electronics. This will be described in Section VII. Plans call for using this combined system for measuring the strength of lines in the (2,0,3), (1,2,3) and (0,4,3) bands of CO_2 at λλ 1.036, 1.049 and 1.063μ in the spectrum of Mars.

Unfortunately, during 14 nights at the telescope poor weather prevented any observation of Mars. However, it is planned to continue observations of Mars through July at least, during which period photo-

graphic observations of the H_2O lines in the Mars spectrum, of the $5\nu_3$ CO_2 band at 0.8660μ and the photoelectric measurement of the telluric O_2 bands will be attempted, with the purpose of searching for possible absorption originating in Mars.

The work with the Fabry-Perot etalon is being done in collaboration with Dr. A. Vaughn, Fellow of the Carnegie Institution of Washington.

c) Magnetic Resonance Spectrometer

The major part of the work involved in the construction and assembly of the sodium vapor resonance spectrometer has been finished and all components are now ready for tests in the Laboratory and at the telescope. However, unexpected difficulties were encountered in obtaining suitable shields for the photomultiplier detectors, which operate in the strong fringe field of the electromagnet. A manufacturer has been found who will construct an annealed shield to specification, through which it is hoped to solve the problem. In this manner, it is expected that in the early summer the instrument may be used at one of the solar telescopes.

VII. Astro-Instrument Development (E.W. Dennison, B.H. Rule and J.B. Oke)

This activity mainly involves the conception, design, construction and testing of advanced peripheral instrumentation useful in astrophysical research. It proceeds under the direct supervision of Dr. E.W. Dennison and Mr. Bruce Rule, and under the general guidance of various astronomers including H.W. Babcock, J.B. Oke, W.A. Baum, G. Münch, I.S. Bowen and R.B. Leighton. Currently, the major effort is devoted to the establishment of fast digital data readouts at the 100-inch and the 200-inch telescopes and the design of a fast nebular spectrograph employing an image tube.

1. 100-inch telescope coudé scanner

During the report period a special effort was devoted to the design and construction of a pulse-counting, spectrum-scanning system urgently

needed by Drs. Münch and G. Neugebauer in their investigations of the atmosphere of Mars, described earlier in this report. This unit consists of two parallel pulse-counting channels, a stepping motor control, and a data assembly and readout control. Each pulse-counting channel consists of a high voltage supply, preamplifier, delay line amplifier, discriminator, pulse shaper and line driver, and a monitoring rate meter. These components are all standard commercial items modified slightly to meet the special needs of this system. In addition, two reversible pulse counters were assembled from logic circuit cards. These counters will count to 1 mc/sec which is substantially beyond the counting speed of any commercially available reversible counter known to this group. One of the counters is a preset counter which acts as control for the gate which determines the counting period. Both counters have six digit capacity.

The stepping motor control moves the spectrograph scanning slit at high speed to a preset limit where the spectrum scan automatically starts. The operator may select a continuous or an incremental mode of spectrum scanning. In the first case, the counters collect data while the spectrum is moving and scanning stops only while data recording is taking place. In the case of the incremental mode, data are collected at each point of the spectrum and the scanner is advanced between each data collection cycle. This unit is also constructed from transistorized digital circuit cards.

The assembly and readout control collects the data from:

i) a fixed data dial;
ii) an encoder which reads the scan slit position to 0.01 Å,
iii) the preset counter, and
iv) the main counter.

These data are sequentially recorded on printed paper tape, and punched into cards for computer analysis. In addition, an analog output is available for "quick-look" monitoring of the spectrum. The visual indicators plus printed paper tape and punched cards provide redundancy to insure the highest readout reliability and accuracy.

The entire unit has been designed to be extremely flexible. Initially it will be used with the preset channel as the spectrum monitor and the main counter as primary data recorder. This, in effect, permits digital ratio recording which is essential for coudè operation where seeing and guiding changes could produce systematic errors or noise in the records which is of a greater amplitude than that expected from the photon flux alone. The preset counter may be used on the scanning slit to permit observation at each point of the spectrum to be made with equal accuracy. Thus, the scanner will spend more time making observations at the bottom of absorption lines where the photon flux is lower.

Great attention has been paid to "human engineering" to reduce operator errors. The unit has been tested with the coudé spectrograph of the 100" telescope, but no actual observations have yet been made due to bad weather during the scheduled observing time. This unit has the potentiality of making major contributions in the area of stellar as well as planetary spectroscopy.

2. 200-inch data system

Plans for the 200-inch telescope data system have continued and the details of the system (described in a current proposal) have been examined. The memory and format control unit has been ordered, as well as some of the component parts. Experience gained in previous projects will enable this unit to be assembled efficiently and the system may be in operation by the end of the next reporting period.

The preliminary simplified data readout system previously constructed and described has been used successfully several times during the period, to measure quasars, white dwarfs, etc. This system permits observations of objects which are approximately 3.5 magnitudes fainter than could be observed with the same spectrograph in the same time using the previous conventional techniques.

3. Cassegrain Observer's Cage (200-inch telescope)

The engineering design and shop drawings for the 200-inch Cassegrain Observer's cage and chair are nearly completed except for electrical control and windup cables. The fabrication and assembly is now underway. The remaining engineering and control design will continue during manufacture.

VIII. Staff and Expenditures

The current staff levels and the expenditures under Grant NsG 426 for the year 1 April 1964 - 31 March 1965 are outlined in the following table, for the various activities described above.

	ACTIVITY	PROF. STAFF	GRAD. STUDENTS	ENGR. and TECH. Full	ENGR. and TECH. Part*	LABOR	MATERIALS	OVERHEAD	TOTAL	BUDGETED
I.	Cosmic Rays	Neher	1	1		5,421	5,075	2,990	13,486	16,180
II.	Cosmic Rays	Vogt Stone	4	4	9	51,006	114,082	19,847	184,935	184,410
III.	Theoretical Astrophysics	Christy	1			8,518	16,304	4,308	29,130	39,500
IV.	Interplanetary Fields and Plasmas	Davis Haerendel Siscoe	3			15,069	5,040	7,401	27,510	31,150
V.	Infrared Astronomy	Neugebauer Leighton Ulrich	3	2	6	51,744	49,047	30,190	130,981	94,100
VI.	Planetary Spectroscopy	Münch Neugebauer Ridgeway	2			11,957	45,297	8,557	65,813	113,500
VII.	Astronomy Instrumentation	Dennison Rule Oke	0	2	1	26,783	87,891	20,218	134,892	128,060
VIII.	Miscellaneous, General Secretarial					4,076	1,721	1,989	7,786	18,100
	TOTAL:								594,533	625,000

* Includes part-time and summertime student technicians

The table indicates that expenditures fairly closely followed the budgeted amounts except for two activities (Nos. V and VI on the table). Because of the close connection of these two activities both in personnel and in research programs it was found convenient to rearrange the costs as indicated in order to avoid unnecessary complications in assigning costs for a given research program to two different accounts. Some of the costs budgeted under Miscellaneous (VIII), such as some of the Publication and secretarial costs, were actually charged to the individual activities concerned. Finally, the indicated expenditures include the outstanding commitments as of 31 March 1965. When the equipment is delivered and work orders are actually completed, the actual costs are usually somewhat greater than the nominal values because taxes, shipping charges, and small cost adjustments are not included in the commitments. The final expenditures will therefore be closer to the budgeted total.

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R.F. Christy "The Dynamics of RR Lyrae Envelopes" Astrophys. J. 68, 275 (1963).

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C.P. Sonett, D.S. Colburn, L. Davis Jr., E.J. Smith and P.J. Coleman Jr. "Evidence for a Collision-Free Magnetohydrodynamic Shock in Interplanetary Space". Phys. Rev. Letters 13, 153 (1964).

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